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RESEARCH DEPARTMENT

AN EXPERIMENTAL VERTICAL APERTURE CORRECTOR

Report No. T-097

(1962/32)

THE BRITISH BROADCASTING CORPORATION
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RESEARCH DEPARTMENT

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AN EXPERIMENTAL VERTICAL APERTURE CORRECTOR

SUMMARY

The principle of operation and construction of a simple experimental vertical aperture corrector is described. The performance of this aperture corrector and some of the problems involved in the design of an operational aperture corrector are discussed.

1. INTRODUCTION

The need for aperture correction of television signal sources is well known and horizontal aperture correction is included in most television systems. The problem of applying vertical aperture correction is more difficult and has for many years virtually been ignored. The development of ultrasonic delay lines, however, has made the construction of a vertical aperture corrector possible.

This report describes an experimental vertical aperture corrector first put forward by W.G. Gibson and A.C. Schroeder of R.C.A.[1] The principle of operation is similar to that of the horizontal aperture corrector known as a derivative equalizer. In the simple practical example to be described approximations to the first and second derivatives are generated.

2. PRINCIPLE OF OPERATION

Gouriet has shown[2] that if a signal is linearly distorted during transmission, the resulting signal can be corrected by adding proportions of its own successive derivatives.

Hence $g(t) \doteq a_0 f(t) + a_1 f'(t) + a_2 f''(t)$

where $g(t)$ is the original signal

$f(t)$ is the distorted signal

$f'(t)$, $f''(t)$ are successive derivatives of $f(t)$

and a_0, a_1, a_2 are constant coefficients.

This method is often used for horizontal aperture correction and can be adapted for use as a vertical aperture corrector by using difference signals to approximate to the derivatives.

The fundamental definition of the first derivative of a function is

$$f'(t) = \lim_{\tau \to 0} \frac{f(t) - f(t-\tau)}{\tau}$$

Hence an approximation to the first derivative can be obtained by subtracting from the function a delayed version of itself. The limitation of the difference method of approximating to a first derivative can be demonstrated by considering a simple sinusoid.

$$\text{Let } f(t) = \sin \omega t$$

$$\text{Then } \Delta_1(t) = \frac{f(t) - f(t-\tau)}{\tau}$$

$$= \frac{2}{\tau}\left[\sin\frac{\omega\tau}{2}\right]\left[\cos\omega\left(t-\frac{\tau}{2}\right)\right] \tag{1}$$

It can be seen that as $\tau \to 0$ the first difference signal $\Delta_1(t)$ approaches the true first derivative $\omega \cos \omega t$. For finite values of τ, however, the difference is only a close approximation to the derivative for small values of ω with respect to $2/\tau$. Fig. 1 shows the departure from the ideal case; it will be seen that the difference signal can only be considered to approximate to the derivative up to a frequency of $1/2\tau$. Successive differences can be similarly produced by introducing more delayed signals.

Aperture correction by adding difference signals is readily applicable to the production of a vertical aperture corrector. If the delay τ is made equal to the duration of one television line, all true horizontal information, being the same for successive lines, will be cancelled, leaving only vertical information. Furthermore the television system can be considered to be a sampling system in the vertical direction, each row of picture elements being sampled in turn. In this case, the maximum frequency which can be carried by the system is $1/2\tau$, and this conveniently is also the maximum frequency up to which the difference signal can be considered to be an approximate derivative.

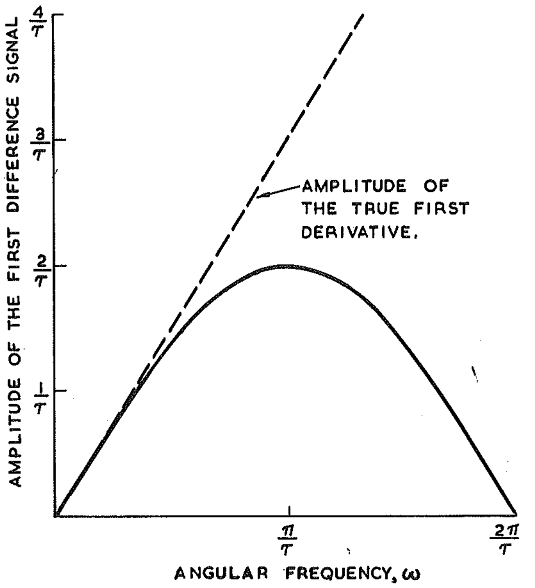


Fig. 1 - Amplitude of the first difference signal versus angular frequency

Most uncorrected television apertures are, in the author's experience, symmetrical and can be corrected by means of even order differences. The simple aperture corrector described in this report was designed primarily to produce a second difference signal.

The second difference signal can be produced by subtraction as follows

$$\Delta_2(t) = \frac{\Delta_1(t) - \Delta_1\,(t - \tau)}{\tau}$$

where $\Delta_1(t)$ and $\Delta_1(t - \tau)$ are first differences

and $\Delta_2(t)$ is the second difference.

Once again it is instructive to consider the case of a simple sinusoid in order to find the limitations of the second difference signal.

Let $f(t) = \sin \omega t$

$\Delta_1(t)$ is given in equation (1)

and it can be shown that

$$\Delta_1(t - \tau) = \frac{2}{\tau} \left[\sin \frac{\omega\tau}{2}\right] \left[\cos \omega \left(t - \frac{3}{2}\tau\right)\right] \tag{2}$$

From equations (1) and (2) it follows that

$$\Delta_2(t) = -\frac{4}{\tau^2}\left[\sin^2 \frac{\omega\tau}{2}\right]\left[\sin\ (t - \tau)\right] \tag{3}$$

As in the case of the first difference it can be seen that as $\tau \to 0$ the second difference $\Delta_2(t)$ approaches the true second derivative $-\omega^2 \sin \omega t$. For finite values of τ, however, the difference is only a close approximation to the derivative for values of ω small with respect to $2/\tau$. Fig. 2 shows the departure from the ideal case; it will be seen that the second difference signal can only be considered to approximate to the second derivative up to a frequency of $1/2\tau$, that is over the same frequency range as applies for the first difference.

It can be seen from equations (1), (2) and (3) that the difference signals are all delayed with respect to the input signal; the first difference signals are delayed by odd multiples of $\tau/2$ and the second difference is delayed by τ. It is necessary for the difference signals to be accurately timed with respect to the signal which they are to correct; therefore the two first-difference signals cannot conveniently be used to correct any of the available signals, but the second difference can be used to correct the input signal delayed by τ.

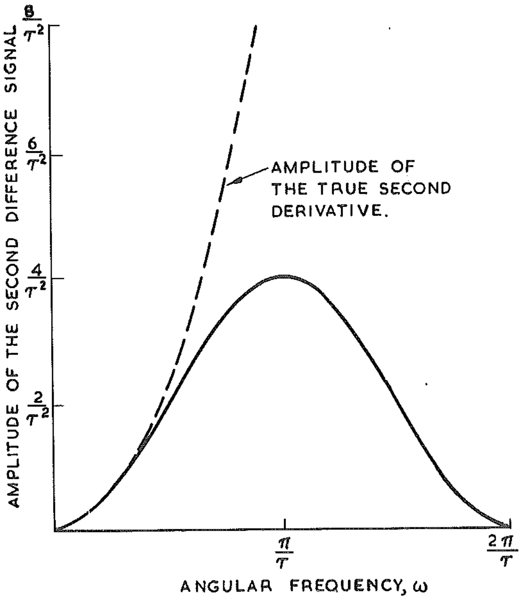


Fig. 2 - Amplitude of the second difference signal versus angular frequency

As the two first-difference signals cannot be used, a considerable circuit simplification can be obtained by not generating them directly. Consider

$$\Delta_2(t) = \frac{\Delta_1(t) - \Delta_1(t - \tau)}{\tau}$$

Substituting for $\Delta_1(t)$ & $\Delta_1(t - \tau)$ their values in terms of the original function we have

$$\Delta_2(t) = \frac{1}{\tau}\left[\frac{f(t) - f(t - \tau)}{\tau} - \frac{f(t - \tau) - f(t - 2\tau)}{\tau}\right]$$

This simplifies to

$$\Delta_2(t) = \frac{1}{\tau^2}\left\{\left[f(t) + f(t - 2\tau)\right] - 2f(t - \tau)\right\} \qquad (4)$$

Thus the second-difference signal can be generated from the appropriate delayed signals by means of two simple adding circuits.

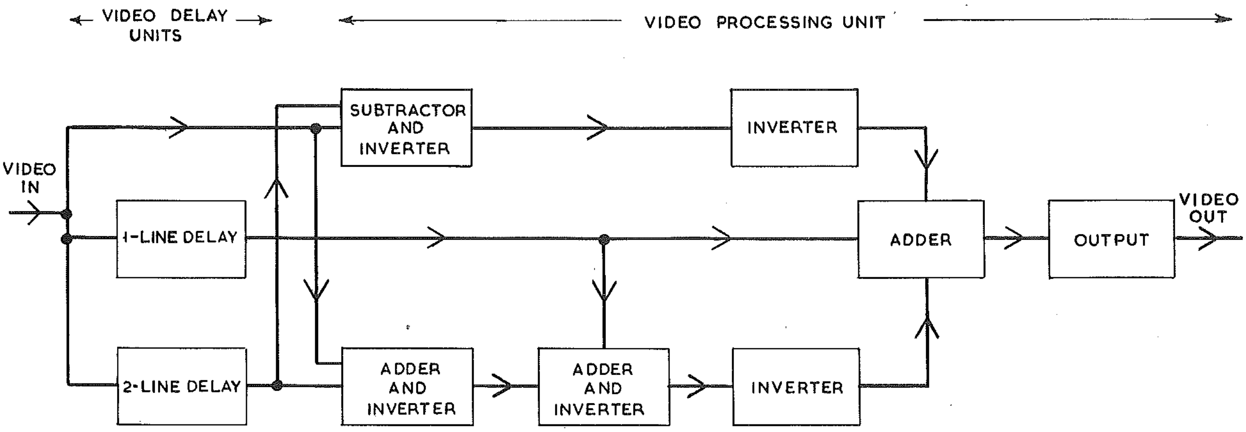
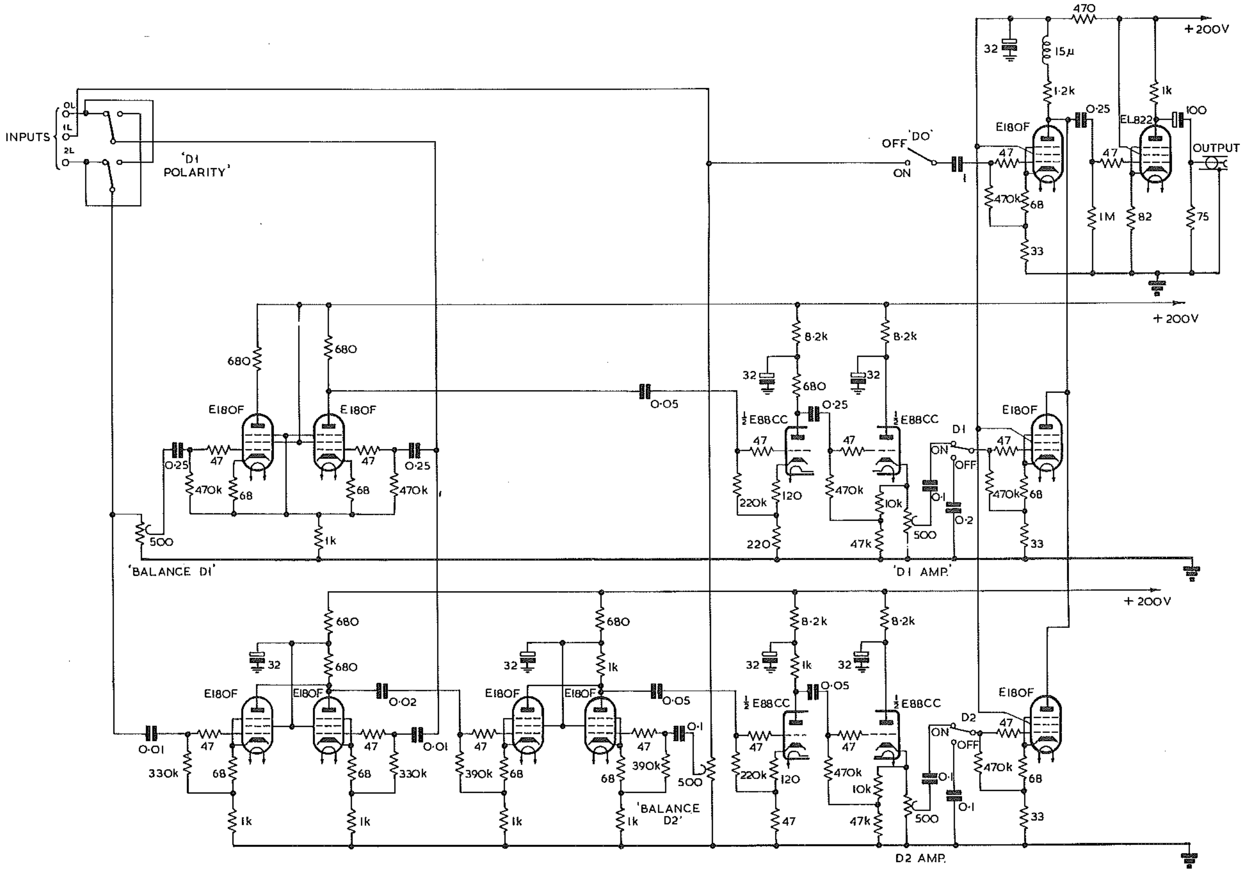


Fig. 3 - Block diagram of the experimental vertical aperture corrector

3. DESCRIPTION OF THE VERTICAL APERTURE CORRECTOR

Fig. 3 is a block diagram of the complete vertical aperture corrector. The necessary delays are produced by means of two video delay units[3] each of which makes use of a continuously variable ultrasonic delay line. These lines were developed by Mullard Research Laboratories and are now commercially available from Mullard Equipment Limited. The input signal and the signals from the video delay units are fed to a video processing unit in which they are added and subtracted according to equation (4); the second-difference signal thus obtained is added to the input signal which has been delayed by one line. The unit also includes a first-difference signal. In order to make this correctly timed with respect to the input signal delayed by one line, the output of the two-line video delay unit is subtracted from the input signal. Hence this difference is only effective over a frequency range of one half that of the second difference.

The complete circuit diagram of the video processing unit is shown in Fig. 4.



Control	Function
D0 On/off	Switches on and off the principal video signal output.
D1 On/off	Switches on and off the first difference signal from the output.
D2 On/off	Switches on and off the second difference signal from the output.
D1 Amplitude	Adjusts the amplitude of the first difference signal in the output.
D2 Amplitude	Adjusts the amplitude of the second difference signal in the output.
D1 Balance	Used to balance the large areas of the picture with only D1 switched on.
D2 Balance	Used to balance the large areas of the picture with only D2 switched on.
D1 Polarity	Reverses the polarity of the first difference signal.

Fig. 4 - Circuit diagram of the video processing unit

4. PERFORMANCE

Before proceeding to describe the performance of the experimental aperture corrector, it must be emphasized that the principal delay used is one television line, but because of the interlace of the television system this is equivalent to two lines of the actual picture. Therefore the maximum frequency which can be corrected is equivalent to two picture elements; the vertical aperture corrector may be compared to a horizontal aperture corrector giving maximum correction at 1·5 Mc/s and zero correction at 3 Mc/s.

In view of this fact, the effectiveness of the experimental aperture corrector was surprising. In order to obtain a subjective assessment of the effect of the corrector on the quality of a television picture, a group of observers was shown a series of moving pictures which was obtained from a high-quality flying-spot 35 mm film scanner. They were asked to assess the picture quality according to the scale:

1. Excellent
2. Good
3. Fairly good
4. Rather poor
5. Poor
6. Very poor

As might be expected, the results of this test showed that the corrector is more effective on some pictures than on others. In every case all the observers voted that the quality of the corrected pictures was better than, or at least equal to that of the uncorrected pictures. The average improvement was voted to be about one grade but in extreme cases an improvement of three grades was registered.

The effectiveness of this rather poor* experimental vertical aperture corrector serves to show how bad the quality of a television picture is in the vertical direction. If the vertical aperture corrector could be made to operate upon successive picture lines it is probable that a further improvement could be achieved. As Gibson and Schroeder pointed out[1], such a vertical aperture corrector could be made if a good quality field-delay were available.

The vertical aperture corrector increases the visibility of random noise and other unwanted signals having components in the vertical direction, such as moiré patterns and stationary noise patterns, for example phosphor grain. In the case of a picture source whose signal-to-noise ratio is marginal, the amount of vertical aperture correction which could be used might be limited by the increase in noise. No separate assessments of these defects have been made; however, the subjective tests indicate that they do not nullify the improvement in picture quality.

5. THE DESIGN OF AN OPERATIONAL VERTICAL APERTURE CORRECTOR

The following points gained from experience with the experimental vertical aperture corrector may be of use to the designer of an operational unit.

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* At least by horizontal aperture corrector standards.

It has been stated that it is essential that the difference signals be accurately timed with respect to the signal which they are to correct. It is estimated that the tolerance on these delays should be plus or minus one-tenth of a picture element. When a crystal-controlled synchronizing pulse generator is used, the ultrasonic delay lines can be adjusted to within this tolerance and will remain within it over long periods of time. When the synchronizing pulse generator is locked to the 50 c/s mains supply, however, frequent readjustment of the delay lines is necessary. Therefore, in an operational unit it would be necessary to servo-control the delay lines in order to maintain the correct timing of the difference signals.

The presence of the difference signals in the output of a vertical aperture corrector can cause excursions of the video signal well below black level, and these can lead to serious synchronizing difficulties. In order to avoid this, a black-level clipper must be included in the output of the unit. Care must be taken to ensure that the blanking and synchronizing pulses which are used to feed the black-level clipper are correctly timed. If "station pulses" which are a television line in advance of the output of the aperture corrector are used, the last line of the picture will occur during the field suppression period and be visible if the display device does not have field fly-back suppressions. It is essential that this should not be able to occur on a transmitted picture.

6. CONCLUSIONS

This simple experimental vertical aperture corrector gives a very significant and worthwhile improvement in picture quality and shows that operational vertical aperture correctors are a practical possibility. A superior form of vertical aperture corrector will become feasible when a high-quality field store becomes available. It is somewhat surprising that the vertical resolution is in general sufficiently poor for the imperfect corrector described to be so effective even on a 405-line television system; it should be even more effective on a system using more lines per field.

7. ACKNOWLEDGEMENT

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8. REFERENCES

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